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(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 111 415 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
27.06.2001 Bulletin 2001/26

(51) Int Cl.⁷: G02B 6/293, G02B 6/34, G02B 6/16, G02B 5/18

(21) Application number: 00120971.7

(22) Date of filing: 27.09.2000

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 21.12.1999 IT TO991125

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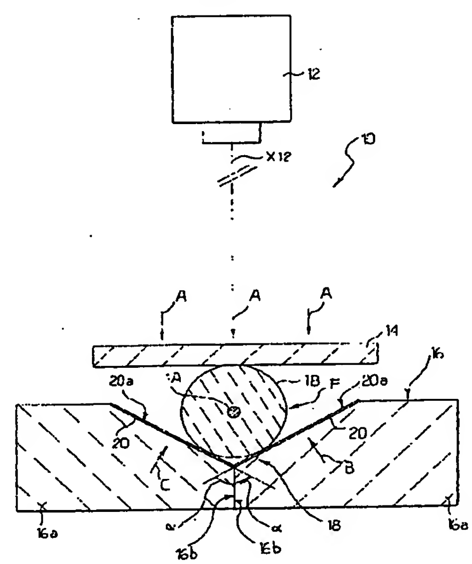
(54) Process and device for making gratings in optical fibres

(57) During the process of writing a grating, the fibre (F) is placed in a support (16) which has a surface cut-out such as a V-shaped groove (18). The side walls (20) of this groove (18) form an angle (α) of 60° with respect to the direction (X12) of propagation of the radiation arriving from the source (12). The aforesaid surfaces (20) have characteristics of high reflectivity with respect to the aforesaid radiation. Consequently, during the writing process, the core (1A) of the fibre (F) is subjected to the action of a plurality of radiation fronts converging on the core. The first radiation front corresponds to the radiation arriving from the source (12) and two other radiation fronts (B, C) are obtained from this radiation by the effect of the reflection from the walls (20) of the surface cut-out of the support (16). The preferred application is to the making of long-period gratings.

Fig_2



EP 1 111 415 A1

FP01-0235-
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SEARCH REPORT

Description

[0001] The present invention relates to gratings made in optical fibres, and relates more specifically to gratings of the type called long-period gratings. These may be, for example, gratings having a period of a few tens of microns (typically 30 - 40 microns), which show a low temperature dependence.

[0002] Devices of this type are known in the art, as demonstrated, for example, by the paper by J.B. Judkins et al., "Temperature-insensitive long-period fiber gratings", published on pages PD1-2 to PD1-5 of the Post-deadline Papers of the OFC Optical Fiber Communication '96 conference held on 29 February 1996, or the paper by V. Bhatia et al., "Temperature-insensitive and strain-insensitive long-period grating sensors for smart structures", published in Opt. Eng. 36 (7), pp. 1872-1876 (July 1997).

[0003] These gratings, whose operation is primarily based on the coupling of a mode guided in the core of the fibre to modes which are propagated in the cladding, have become useful for applications in sensor technology and optical telecommunications, for example for use in band-rejection filters or gain equalizers for optical amplifiers. Unlike short-period gratings, long-period gratings do not backscatter the resonance wavelength.

[0004] For making these gratings, a corresponding length of optical fibre is subjected to the action of a radiation source, such as a frequency doubled argon laser, capable of causing a local variation of the refractive index in the core of the fibre. The profile (typically the period) of the variations of the refractive index induced in this way is determined by the characteristics of a writing mask interposed between the radiation source and the fibre. The mask, typically produced by photolithographic or similar methods, is made in such a way as to expose to the radiation, or mask from it, the successive areas of the fibre core in which the refractive index is to be changed or kept unaltered respectively.

[0005] In Figure 1 of the attached drawings, the curve indicated by A represents the propagation characteristics (in terms of attenuation - vertical scale, measured in dB) of a long-period grating made according to the known art. The attenuation is shown here as a function of the wavelength (λ - horizontal axis, measured in nm) with reference to a non-polarized radiation. The diagram clearly demonstrates the band-rejection filter characteristics shown by the grating in the area lying essentially between 1510 and 1530 nm. The fact that the curve A reproduced here shows an attenuation value of approximately 2 dB even outside the aforesaid area is due solely to the experimental set-up used for plotting the diagram.

[0006] On the other hand, the graph of the curve B, relating to the same grating, represents the variation (again measured as a function of the wavelength λ) of the parameter known as PDL, an abbreviation of "polarization dependent loss". In gratings made according to the known art, it is usual to find markedly differentiated behaviour in the presenc of two optical radiations having polarizations orthogonal to each other. The form of the curve B in Figure 1 demonstrates, above all, that this diff rence in b haviour, which is hardly perceptible outside the area in which the grating performs its filtering action, becomes very considerable (showing especially a rather irregular variation as a function of the wavelength λ) within the area in which the grating carries out its function as a band-rejection filter.

[0007] Without wishing to adopt any specific theory in respect of this matter, the applicant has reasons for thinking that this behaviour (which is such that the grating acts to a certain extent as a polarizer) is intrinsically related to the fact that, during the operation of writing the grating, the refractive index of the fibre core loses its characteristic of an essentially scalar value and assumes the characteristics of a tensorial value.

[0008] The object of the present invention is to overcome the aforesaid drawback in such a way that it is possible to make long-period in-fibre gratings in which the aforesaid polarization dependence is virtually eliminated.

[0009] According to the present invention, this object is achieved by means of a process having the characteristics claimed in a specific way in the following claims. The invention also relates to a device which can be used for the application of this process.

[0010] The invention will now be described, purely by way of example and without restriction, with reference to the attached drawings, in which:

- Figure 1, relating to the characteristics of the known art, has already been described above;
- Figure 2 shows schematically the structure of a device operating according to the invention; and
- Figure 3 shows, in a way essentially corresponding to that of Figure 1, the characteristics of a grating made according to the invention.

[0011] In Figure 2, the reference numeral 10 indicates as a whole a device which can be used to make a long-period grating in a length of optical fibre F comprising a core 1A surrounded by a cladding 1B.

[0012] The grating is produced in a known way by illuminating the core 1A with the radiation emitted by a source 12 (for example a frequency doubled argon laser) through a mask 14 which has a succession of areas which are opaque and transparent to the radiation emitted by the source 12.

[0013] Instead of simply resting on a support (e.g. a plate of silica located in a position diametrically opposite the mask 14), the fibre F, in the device 10 according to the invention is associated with a support 16 provided with a surface cut-out such as a V-shaped groove 18, to enable the operation of writing the grating to take place.

[0014] The groove 18, capable of containing at least part of the fibre F within it, is made with a symmetrical

V-shape forming an ideal dihedral whose opening angle is 120°.

[0015] As obs rved from the viewpoint of Figure 2, each of the sides or flanks 20 of the groove 18 therefore lies in a plane inclined at an angle α of 60° to the direction of propagation of the radiation arriving from the source 12. In Figure 2, this direction of propagation is indicated by X12.

[0016] The support 16 can be made, for example, from two plates 16a (of silica or quartz, for example), which are initially subjected to a chamfering operation so that each forms one of the planes 20 constituting the sides of the groove 18, and which then have their two rectilinear sides 16b, adjacent to the areas subjected to chamfering, placed next to each other.

[0017] Provided that the described geometry is retained, the procedures for forming the groove 18 can be completely different: in particular, the support 16 can consist of a single piece of material subjected to machining.

[0018] The material forming the support 16 can also be different from those indicated, subject to the retention of the requirement to provide good characteristics of dimensional stability, the possibility of shaping the sides 20 as plane surfaces and (especially because of the possible applications in combination with a source 12 of high power) the capacity of providing good characteristics of heat dissipation.

[0019] Preferably (and particularly when this does not result directly or virtually directly from the operation leading to the formation of the sides 20), a coating layer 20a, capable of showing a high degree of surface reflectivity combined with good characteristics of resistance to the radiation generated by the source 12, is formed on or applied to the support 16, at least on the sides 20 of the groove 18.

[0020] The radiation arriving from the source 12 (shown in Figure 2 schematically and with its dimensions reduced to meet the evident requirements of illustration) is propagated in the direction indicated by the arrows A, passing through the mask 14 and then striking the fibre F and in particular the core 1A. However, the characteristics of high reflectivity of the sides 20 of the groove 18 have the effect of causing the radiation arriving from the source 12 (and in particular the fraction of it which is propagated in a grazing direction with respect to the fibre F) to strike the sides 20 of the groove 18 and then to be reflected towards the fibre F in the directions of propagation indicated by the arrows B and C in Figure 2.

[0021] In the parts corresponding to the transparent areas of the mask 14, the fibre F, and in particular its core 1A, is thus struck by three radiation fronts which are propagated towards the core 1A in three different directions, separated from each other by angles of 120°.

[0022] Because of the high degree of reflectivity imparted to the sides 20 of the groove 18, the three radiation fronts generated in this way (the first one directly by the source 12, acting as a first generator, the oth r two by the sides 20 of the groove 18 provided in support 16, these sides acting as further generator means by way of reflection) have levels of intensity which are essentially identical to each other.

[0023] Experiments conducted by the applicant demonstrate that this procedure, and in particular the fact of making the grating by irradiating the fibre F with a plurality of radiation fronts which strike the core 1A in a plurality of different angular directions (distributed in a uniform or essentially uniform way in space), is such that, although its value is varied by the effect of the irradiation, the refractive index of the core 1A of the fibre retains characteristics of essential uniformity over the whole section of the core 1A.

[0024] The result which can be achieved with the solution according to the invention is represented by the curves reproduced in Figure 3 and identified by A and B respectively in a similar way to that used in Figure 1. Figure 3 shows the characteristics of propagation of an in-fibre grating essentially similar to that considered with reference to Figure 1.

[0025] The results documented in Figure 3 demonstrated that, for an equivalent behaviour as a band-rejection filter (curve A), the variation of the PDL (graph B), when compared with the corresponding graph in Figure 1, is rather more regular, possibly because the maximum values of PDL measurable in the band rejection area are rather low, especially if compared with the variation of the same parameter outside this area.

[0026] Theoretically at least, it would be possible to consider increasing the number of radiation fronts striking the core 1A. This result can be obtained, for example, by using mechanisms for splitting the radiation arriving from the source 12 between different optical paths designed to be directed back towards the core 1A of the fibre F.

[0027] However, the solution shown in Figure 2 is to be considered preferable, at the present time at least, since it enables excellent results to be obtained with a simple device. All of this is done with the further advantage due to the fact that the two radiation fronts indicated by the arrows B and C of Figure 2 are obtained directly (by simple reflection) from the principal wave front represented by the arrows A after this front has passed through the mask 14.

[0028] The reflective sides 20 of the groove 18 can, if necessary, be subjected to machining and/or treatment designed to enable the sides 20 to provide a slight focusing action in respect of the radiation incident on them. However, the experiments conducted by the applicant demonstrate that this refinement is superfluous in most cases.

[0029] In the light of these considerations, therefore, it is clear that, provided that the principle of the invention is retained, the details of production and the forms of embodiment can be widely varied from those described and illustrated without departure from the scope of the

present invention.

Claims

1. Process for making gratings in an optical fibre (F) comprising a core (1A) surrounded by a cladding (1B), the process comprising the operation of inducing local periodic variations of the refractive index of the said core (1A) by exposure to a radiation having corresponding periodic variations of the intensity, characterized in that the said variations of the refractive index are induced by exposing the said core (1A) to a plurality of radiations (A, B, C) which strike the core (1A) in respective directions distributed angularly in an essentially uniform way.

2. Process according to Claim 1, characterized in that the said plurality of radiations comprises three radiations (A, B, C).

3. Process according to Claim 1 or Claim 2, characterized in that the said plurality of radiations (A, B, C) is obtained from a single radiation source (12).

4. Process according to any one of the preceding claims, characterized in that, of the said plurality of radiations, a first radiation (A) is sent directly towards the fibre (F), while the other radiations (B, C) are sent towards the fibre (F) after being subjected to reflection.

5. Process according to Claim 3 and Claim 4, characterized in that it comprises the operation of providing, for the generation of each of the said other radiations (B, C), a respective reflective surface (20) capable of being struck by the said first radiation (A) and of redirecting the said first radiation (A) towards the said core (1A) as a result of reflection.

6. Process according to Claim 5, characterized in that it comprises the operation of providing two of the said reflection surfaces (20), forming jointly a receiving cut-out (18) for the fibre (F) in which the grating is made.

7. Process according to Claim 5 or Claim 6, characterized in that the said respective reflective surface (20) lies in a plane forming an angle (α) of 60° to the direction (X12) of propagation of the said first radiation (A).

8. Process according to any one of the preceding claims, characterized in that the said grating is a long-period grating.

9. Device for making gratings in an optical fibre (F) comprising a core (1A) surrounded by a cladding (1B), the device comprising generator means (12, 14) for generating a radiation having local periodic variations of intensity capabl of inducing corresponding periodic variations of the refractive index of the said core (1A), characterized in that the said generator means (12, 14) are associated with further generator means (16, 18, 20) and interact with these to generate a plurality of radiations (A, B, C) which strike the said core (1A) in respective directions distributed angularly in an essentially uniform way.

10. Device according to Claim 9, characterized in that the said generator means comprise:

    - a radiation source (12) for sending a first radiation (A) of the said plurality towards the fibre (F),
    - a mask (14) interposed in the path of propagation of the said first radiation (A) from the said source (12) towards the said fibre (F), for generating the said local periodic variations of intensity of the radiation, and

    the said further generator means comprise:

    - a support (16) for the fibre (F), and
    - reflection means (20) associated with the said support (16) and capable of being struck by the radiation produced by the said source (12) in such a way as to generate, by reflection, other radiations (B, C) of the said plurality, directed towards the said core (1A).

11. Device according to Claim 10, characterized in that the said reflection means comprise reflective surfaces (20) lying in respective planes forming an angle of 60° to the direction of propagation (X12) of the said first radiation (A).

12. Device according to Claim 11, characterized in that the said support (16) comprises two of the said reflective surfaces (20).

13. Device according to Claim 12, characterized in that the said reflective surfaces (20) jointly form a cut-out of the said support (16) capable of receiving at least part of the said fibre (F).

14. Device according to Claim 12 or Claim 13, characterized in that the said support (16) consists of two plate elements (16a), each provided with a respective one of the said reflective surfaces (20), with the said reflective surfaces (20) placed adjacently to each other.

Fig_1

KNOWN ART

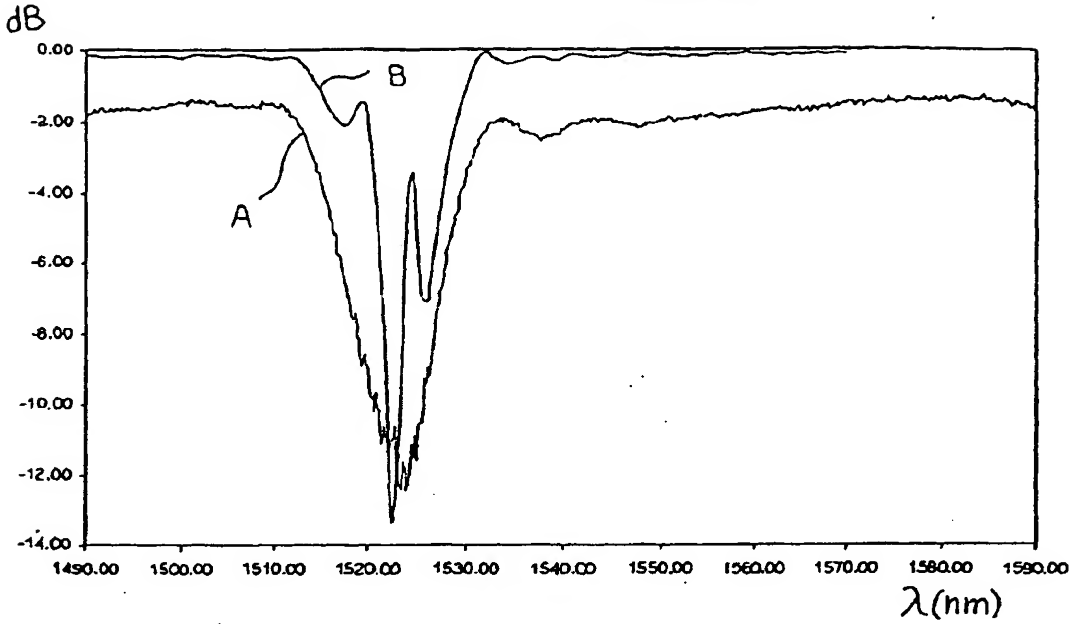


Fig_3

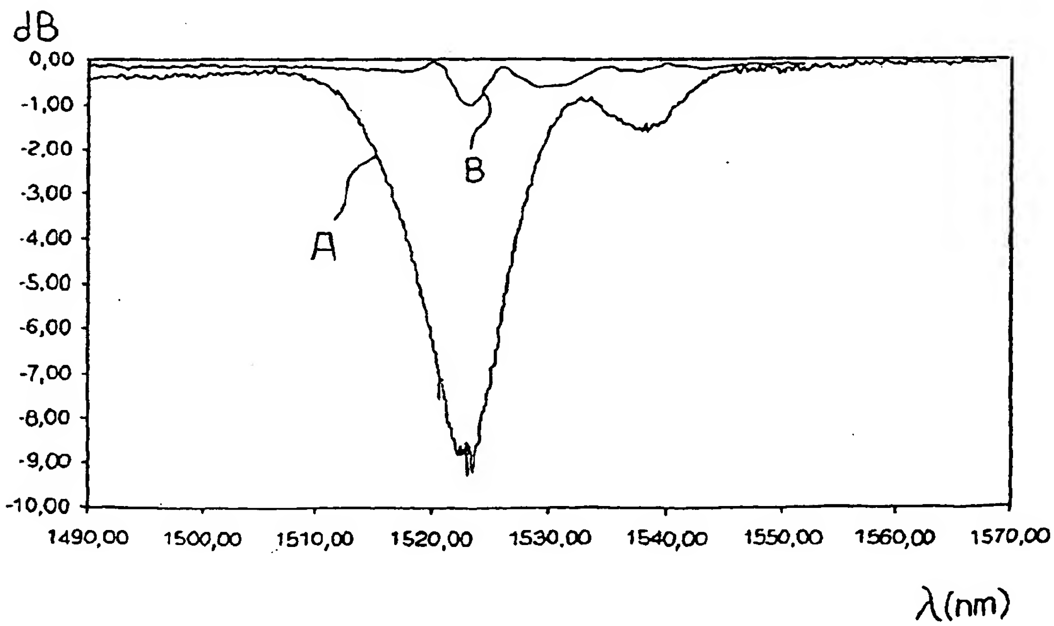
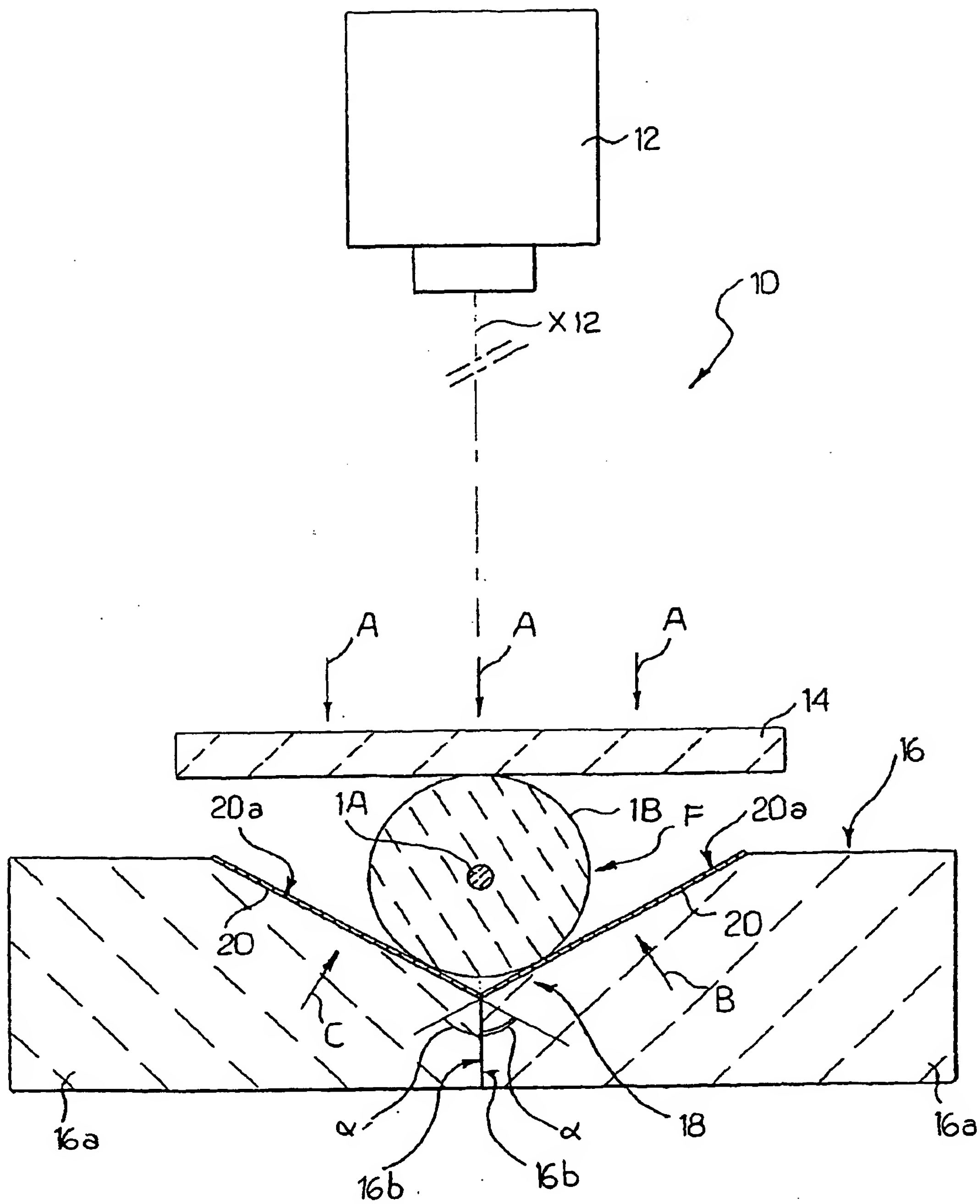


Fig_2



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EUROPEAN SEARCH REPORT

Application Number
EP 00 12 0971

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	3 April 2001	Mathyssek, K

CATEGORY OF CITED DOCUMENTS

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